WINDS OF THE UPPER TROPOSPHERE AND LOWER STRATOSPHERE OVER THE UNITED STATES

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ABSTRACT

Daily wind data from United States stations for six pressure surfaces (200, 150, 100, 80, 50, 30 mb.) for the period April 1951 through January 1956 are used to study upper winds along the 80th and 120th meridians. At 5-degree intervals along the two meridians, mid-season average wind speeds and prevailing directions have been computed and are compared.

1. INTRODUCTION

The climatology of the upper air, particularly that area above 40,000 feet has been neglected because of the lack of sufficient data. During recent years, with rapid improvements in instrumentation and techniques, an increasing supply of wind data at higher elevations has become available [1]. Although the amount of data has not reached its maximum, sufficient data are now available to establish certain climatological relationships.

Winds over the United States for four mid-seasonal months are compared from latitude 25° N. through 45° N. along longitude 80° W. and from latitude 35° N. through 50° N. along longitude 120° W. This study is confined to the upper troposphere and the lower stratosphere, specifically between the 200-mb. level (about 40,000 feet) and the 30-mb. level (about 80,000 feet). Data used are 1500 GMT rawin observations for a period beginning April 1951 and ending with January 1956. Pilot balloon observations were not used because they are few in number and often considered questionable at these altitudes.

For most of the period, sufficient data were available to obtain climatological averages for single stations. However, this was not possible for the first years of the period for the mid-season months of January, April, and October. Where necessary, data from several nearby stations were combined to arrive at a representative value. The persistence of winds at higher altitudes justifies this procedure.

The 5-year wind speed averages were plotted on maps. Isolines and wind roses were drawn and data for the 5-degree latitudinal intersections of the meridian were interpolated. The arithmetical wind speed averages were then plotted on graphs, and vertical profiles were drawn (figs. 1–8). No subjective interpretations were made in drawing the curves. A very few subjective interpretations were made for prevailing wind directions. In no case was the change more than to the adjacent direction.

In the graphs, prevailing directions are to 16 compass points (i. e., N, NNE, etc.). The first number in parentheses is the percentage of occurrence of the prevailing wind direction. The second number is the percentage of occurrence of the prevailing direction plus the two adjacent directions. (Example: E(50, 75). Prevailing direction east 50 percent of the observations; directions ESE, E, ENE 75 percent of the observations). Small prevailing direction percentages indicate that the directions are fairly well dispersed around the compass.

The phrase "transition zone" is used in the discussion of the graphs to denote the region of minimum wind speed. Decreasing westerly winds in this region usually change rapidly with height to increasing easterlies. This rapid change in the winds is most common during the spring, summer, and fall seasons for southern latitudes and the summer season in northern latitudes.

A good example of the seasonal march of the transition zone is found in comparing two curves which are nearly identical. These are shown by the curves for July 40° N., 80° W. (fig. 5) and October 25° N., 80° W. (fig. 7).

Since this study was based on observed values alone, the possibility of bias toward lower wind speeds in the final results was considered. To assess this effect, synoptic situations for various periods and for stations with abundant data during this period were studied rather thoroughly. The following conclusions bearing on this paper were reached: (1) the layer above the 200-mb. level is above the maximum wind level a large percentage of the time, and therefore decreasing values would be expected with height until the transition zone is reached; (2) high winds would affect the amount of data primarily because the rawinsonde balloon was blown out of range before the 200-mb. level was reached, therefore the levels above the 200-mb. level themselves could not be classified "high-wind" levels for this reason; (3) the abundance of data for the 5-year period would tend to correct the bias toward a reasonable climatological average; (4) the persistence of winds from day to day at these elevations made it possible to detect trends of both lower and higher speeds when values were missing. For these reasons it is believed that the mean values derived can be considered substantially accurate.

The values derived from this study compare closely with those of Kochanski and Wasko [2, 3, 4]. These similarities occur despite different techniques used, and should, therefore, increase confidence in the climatological value of both methods. Similar agreement may be found between these values and geostrophic values from

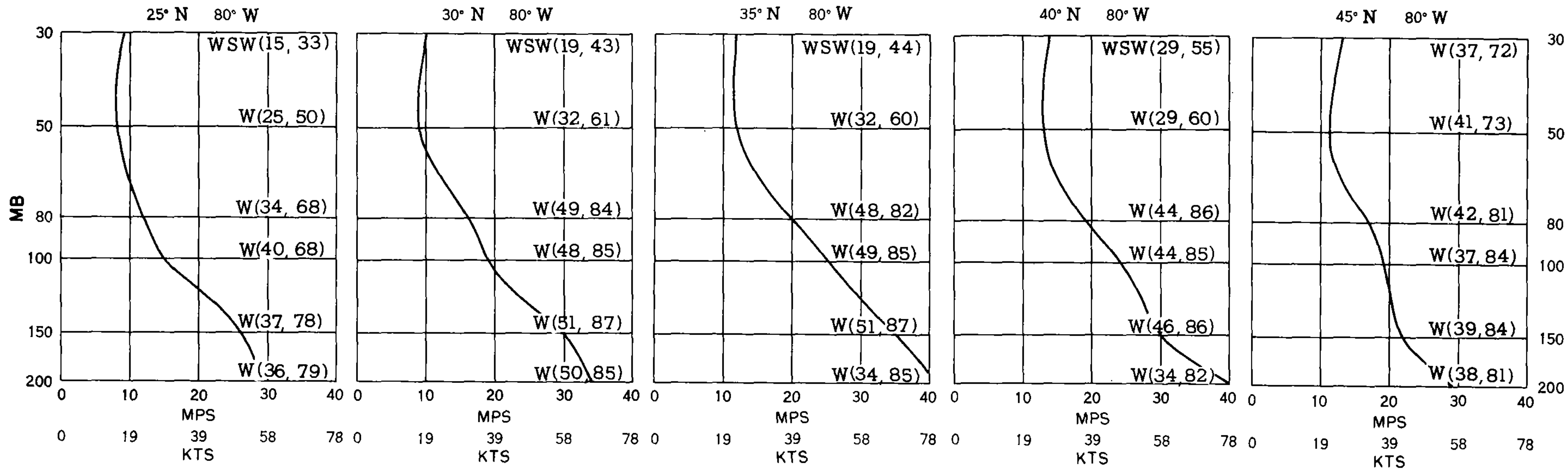

FIGURE 1.—January, 80° W. Average speed and prevailing direction of winds, 200-mb. to 30-mb. levels, from 25° to 45° N. Based on data for 5-year period January 1952–56. Letters at right of each diagram show prevailing direction. First number in parentheses shows percentage of occurrence of prevailing wind direction, second number, percentage of occurrence of the prevailing direction plus the two adjacent directions.

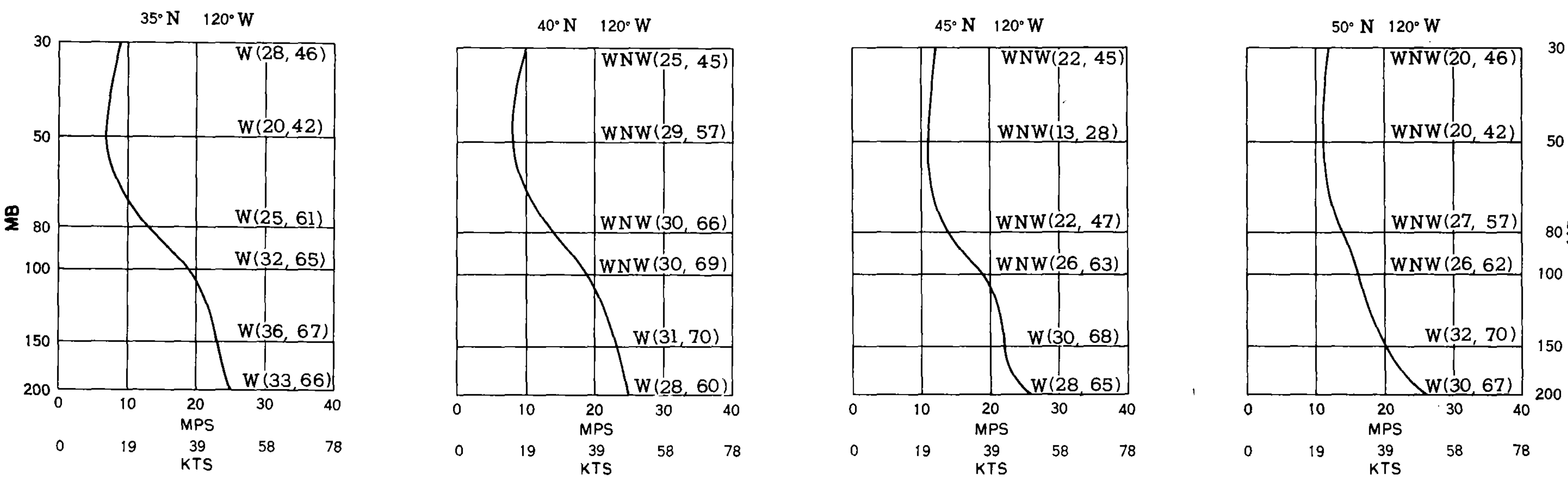

FIGURE 2.—January, 120° W. Average speed and prevailing direction of winds, 200-mb. to 30-mb. levels, from 35° to 50° N. Data for period January 1952–56.

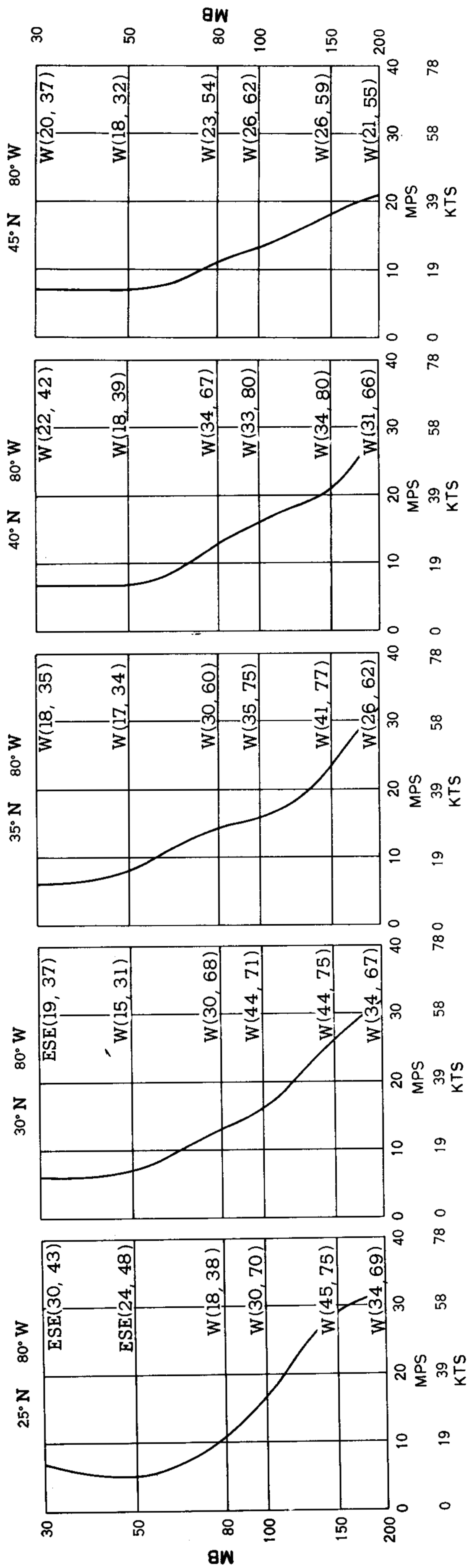

FIGURE 3.—April, 80° W. Average speed and prevailing direction of winds, 200-mb. to 30-mb. levels, from 25° to 45° N. Data for period April 1951–55.

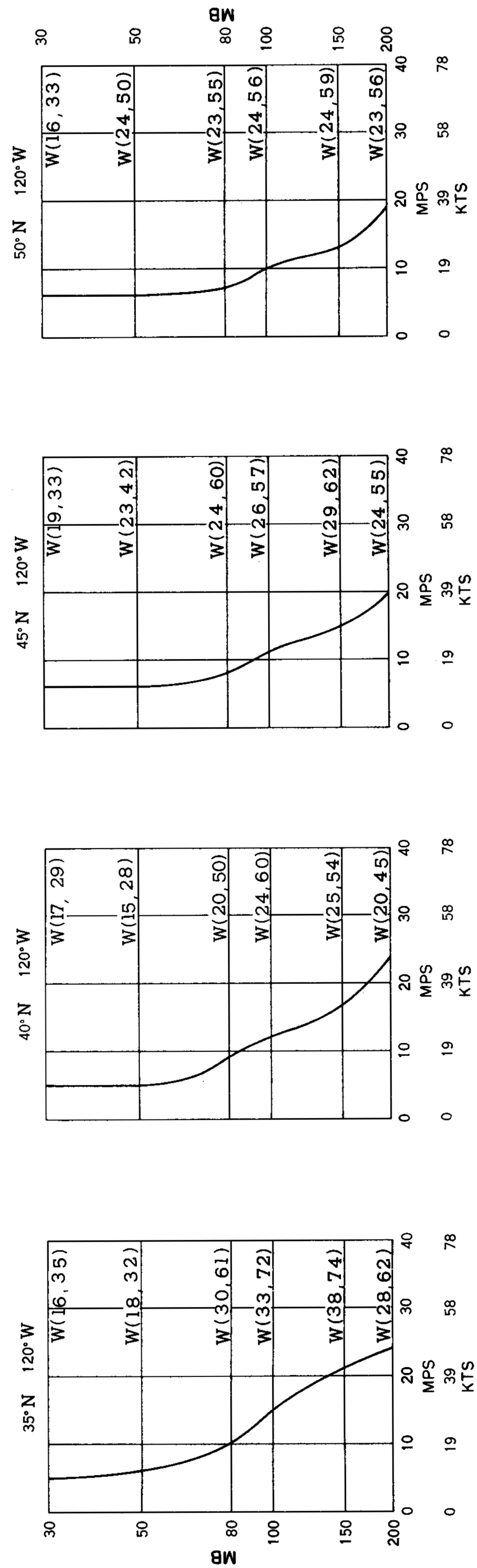

FIGURE 4.—April, 120° W. Average speed and prevailing direction of winds, 200-mb. to 30-mb. levels, from 35° to 50° N. Data for period April 1951–55.

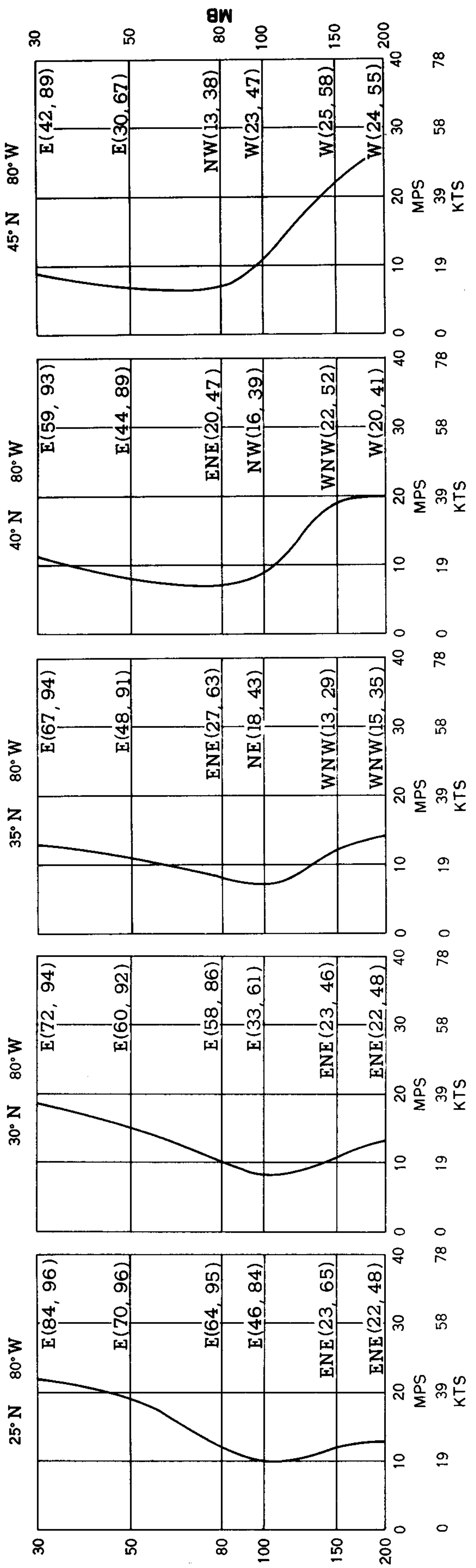

FIGURE 5.—July, 80° W. Average speed and prevailing direction of winds, 200-mb. to 30-mb. levels, from 25° to 45° N. Data for period July 1951–55.

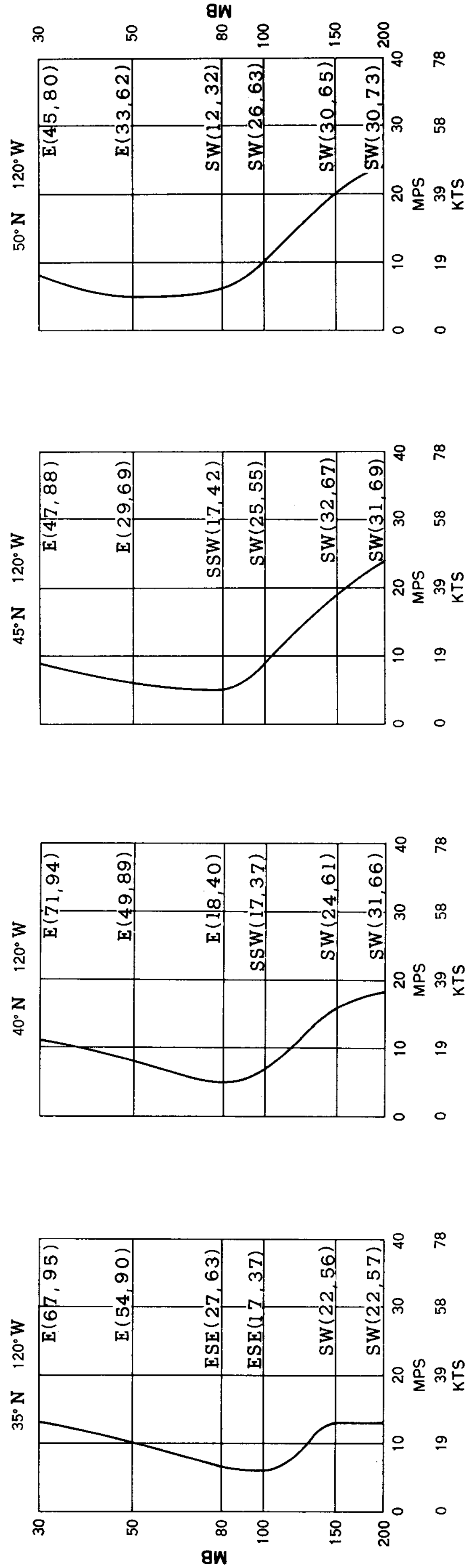

FIGURE 6.—July, 120° W. Average speed and prevailing direction of winds, 200-mb. to 30-mb. levels, from 35° to 50° N. Data for period July 1951–55.

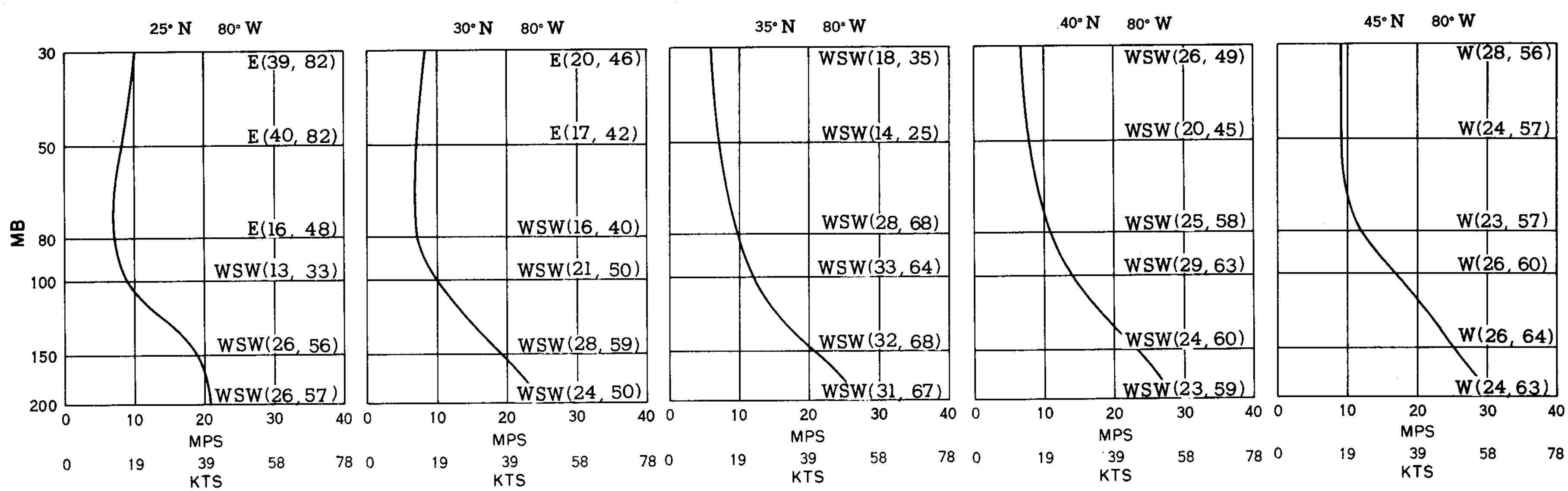

FIGURE 7.—October, 80° W. Average speed and prevailing direction of winds, 200-mb. to 30-mb. levels, from 25° to 45° N. Data for period October 1951–55.

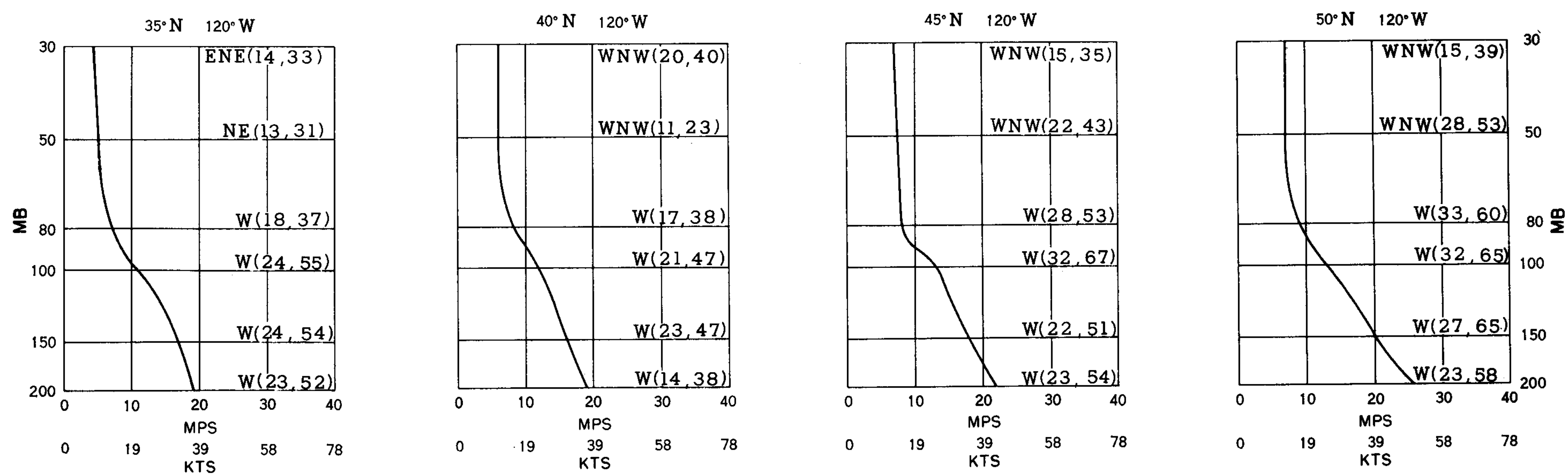

FIGURE 8.—October, 120° W. Average speed and prevailing direction of winds, 200-mb. to 30-mb. levels, from 35° to 50° N. Data for period October 1951–55.

upper air maps [5, 6]. Percentage frequencies of the prevailing direction and adjacent directions facilitate assessment of the relative variability or constancy of wind direction.

2. MID-SEASONAL WIND PROFILES

JANUARY

Longitude 80° West (fig. 1).—The wind speeds at all latitudes decrease with height to the 50-mb. level and then become steady or increase 1 or 2 meters per second to the 30-mb. level. The faster the wind speed at 200 mb. the more rapid is the decrease from level to level. Between the 200-mb. and 80-mb. levels the speed increases from latitudes 25° to 35° N. A small decrease in speed occurs, at these levels, at latitude 40° N. and a decided decrease is observed at latitude 45° N.

The prevailing wind direction for all latitudes between the 200-mb. and 50-mb. levels is west. At the 30-mb. level from 25° to 40° N. the prevailing direction is west-southwest. Short periods of easterly winds are observed at the higher levels. This slight tendency for easterly winds is more prevalent in the lower latitudes.

Longitude 120° West (fig. 2).—The wind speeds at all latitudes decrease with height to the 50-mb. level and then increase from 1 to 2 meters per second to 30 mb. Speeds are approximately the same, along the meridian, from 200 mb. through 80 mb. There is a tendency for increasing speed in the higher latitudes above 80 mb.

The unformity of wind speed, with increasing latitude along the 120th meridian, contrasts sharply with the more extreme changes along the 80th meridian. The average speeds, level by level for comparable latitudes, are lower than those along the 80th meridian.

The prevailing wind direction is west between the 200-mb. and 150-mb. levels for all latitudes. Between the 100-mb. and 30-mb. levels from 40° to 50° N. the prevailing direction is west-northwest. Easterly winds occur most frequently at the higher levels and are of short duration.

APRIL

Longitude 80° West (fig. 3).—The wind speed curves for January and April are similar in appearance but several important changes have taken place. At the 200-mb. level the average speeds for April are approximately the same from 25° to 40° N. The speeds in the lower levels at 25° N. are greater than in January. Speeds in the lower level from 30° to 45° N. are lower than they were in January. There is a 10 meters per second decrease in speed at 200 mb. from 40° to 45° N. At 25° N. the speed decreases from 200 mb. to 50 mb. and then increases slightly. At other latitudes it decreases to 50 mb. and then decreases more slowly or remains constant.

West winds prevail at all latitudes and levels with the exception of the 30-mb. level at 30° N. and the 50-mb. and 30-mb. levels at 25° N. where the prevailing wind direction is east-southeast.

Longitude 120° West (fig. 4).—The wind speed from 35° to 40° N. is greater in the lower levels and less in the upper levels than from 45° to 50° N. The speed decreases with height to 80 mb. and then decreases more slowly or remains constant at all latitudes.

Comparing the wind speed curves along the two meridians it is found that the greatest difference is in the lower levels. The higher speeds are found along the 80th meridian. For the higher levels, all curves are nearly identical.

The prevailing wind direction for all latitudes and levels is west. Short periods of easterlies are observed in the upper levels.

JULY

Longitude 80° West (fig. 5).—The wind speeds and directions for July differ substantially from those of the other mid-seasonal months in that the transition zone is easily found at all latitudes. The transition zone is lower (generally at the 100-mb. level) from 25° to 35° N., and moves upward (80 mb. to 50 mb.) with increasing latitude. Below the transition zone, wind speeds are light in the lower latitudes, increasing northward, so that at 45° N. the 200-mb. speeds are higher than those of April. Above the transition zone there is a rapid increase in speeds in the southern latitudes. This increase becomes smaller with increasing latitude and appears to be associated with the variability of the altitude of the transition zone.

Easterly winds prevail at all levels from 25° to 30° N. With increasing latitude, below the transition zone, directions gradually change until at 45° N. the prevailing direction is west. Above the transition zone, easterly winds predominate at all latitudes. Generally, winds that are westerly at the 200-mb. level remain westerly, with increasing height, to the transition zone and then turn easterly. The sense of the change to an easterly direction may be either clockwise or counterclockwise depending upon the final westerly direction (i. e., northwesterly winds turn through north and northeast (fig. 5); southwesterly winds turn through south and southwest (fig. 6)).

Longitude 120° West (fig. 6).—The trend of changing speeds during July at 120° W. compares very closely with that of the 80° W. meridian. There is a definite transition zone at all latitudes ranging from 100 mb. at 35° N. to 50 mb. at 50° N. Speeds below the transition zone are generally light at 35° N., increasing northward. There is a more rapid decrease from level to level at the higher latitudes. Speeds in the transition zone are the same for all latitudes. Above the transition zone, speeds increase moderately in southern latitudes and only slightly in northern latitudes.

Southwest winds prevail below the transition zone; easterly winds prevail above the transition zone.

OCTOBER

Longitude 80° West (fig. 7).—The transition zone which was present for all latitudes for July, has now disappeared at the northerly latitudes, and has moved upward to the 80-mb. level at 25° and 30° N. Speeds above this zone increase only slightly (2 to 3 meters per second). It is interesting to note the steady increase in the 200-mb. speed from 25° to 45° N., which produces a rapid decrease from 200 mb. to 80 mb. at the northerly latitudes. The curves at 35°, 40°, and 45° N., are similar except that the speeds at the higher latitudes are greater, level for level, and tend to become more uniform with increasing height.

Prevailing directions are westerly at all levels from 35° to 45° N. From 25° to 30° N. they are west-southwest below the transition zone and east above it. Periods of easterlies are observed at all latitudes, but they are of short duration and become less frequent with increasing latitude.

Longitude 120° West (fig. 8).—The October trend at 120° W. differs from that at 80° W. only slightly. Speeds in the lower levels increase at a uniform rate with increasing latitude but tend to remain nearly constant above the 50-mb. level. At the 120th meridian speeds in the lower levels average about 20 percent less than those for equal latitudes at the 80th meridian, and in the upper levels about 10 percent less.

Prevailing directions are from the west in the lower levels at all latitudes. They are west-northwest in the higher levels with the exception of slight, perhaps insignificant, predominance of easterly winds at 35° N. Short periods of easterlies are observed but are more frequent, of longer duration, and at lower elevations in the southerly latitudes.

3. CONCLUSION

The most striking dissimilarity between the speed curves for January and curves for the mid-seasonal months of April, July, and October for 80° W. is the consistently higher speeds that occur from 200 mb. through 50 mb. Speeds in January along this longitude average 23 percent higher than in April, 37 percent higher than in July, and 30 percent higher than in October. At 80° W. the mean January speed averages 25 percent higher than for the same points at longitude 120° W. This ratio is greater (about 40 percent) at 35° and 40° N. than for other latitudes. The reason seems to be that the underlying jet stream activity is more persistent across 80° W. at these two latitudes.

Latitudinally, the largest decrease in speed with height at both meridians is at 35° and 40° N. for all seasons. This, of course, takes into consideration the increase in speeds from the 100-mb. to 30-mb. levels during July. Along the 80th meridian the highest 200-mb. speeds are found at 35° N. during January, and the highest 30-mb. speeds are found at 25° N. during July. At 120° W., 200-mb. speeds are approximately the same in January at all latitudes, and the 30-mb. speeds reach a maximum at 35° N. in July.

Comparison of the relative speeds along the two meridians shows the greatest difference for the four seasons is along latitude 35° N. The speeds along the 80° W. meridian are much higher than those along the 120° W. meridian. The curves for the two longitudes shown on the accompanying graphs are approximately the same at 45° N. with the exception of the October curve. It can readily be seen that, disregarding the relative speeds, the curves closely resemble each other in nearly all cases.

The prevailing wind directions are westerly at all latitudes, below the transition zone, with the exception of easterly winds during July at 25° and 30° N. Above the transition zone in summer, the wind seldom varies from a direction between east-northeast and east-southeast. Variability of wind direction is greatest in the region of the transition zone. When no transition zone is present dispersion is greatest in the highest levels.

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